Southern California Association of Governments

Regional High-Occupancy Vehicle Lane System

PERFORMANCE STUDY

FINAL

Summary Report

November 4, 2004

Leadership

Vision

Progress

SCAG MISSION STATEMENT

Leadership, vision and progress which promote economic growth, personal well-being, and livable communities for all Southern Californians.

The Association will accomplish this Mission by:

- Developing long-range regional plans and strategies that provide for efficient movement of people, goods and information; enhance economic growth and international trade; and improve the environment and quality of life.
- Providing quality information services and analysis for the region.
- Using an inclusive decision-making process that resolves conflicts and encourages trust.
- Creating an educational and work environment that cultivates creativity, initiative, and opportunity.

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9.07.04

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EXECUTIVE SUMMARY

"HOV gap closures that significantly increase transit and rideshare use will be supported and encouraged...." – 2004 RTP

Introduction

High Occupancy Vehicle Lanes, also known as rideshare/carpool lanes, are very popular with the traveling public, enjoying 76% study area support and have become an integral component of Southern California's transportation system.

Since the first HOV lane opened in 1976 in the region (the El Monte Busway, located along on Interstate 10 in Los Angeles County) the HOV system increased to 54.9 lane miles in 1990 to 664 lane miles in 2000 (see Table 1). An additional 739 HOV lane miles are planned for construction by 2030 (see figure 2), for a regional total of 1,430 lane miles and an 1,100% increase in HOV lane mileage. Ventura and Imperial Counties do not currently have any existing or planned HOV lanes.

Figure 1 – Study Area

By comparison, nationally, HOV lanes have grown from 700 miles in 1990, to 3,000 lane miles in 2004, to an estimated 3,700 lane miles by 2010 or a 329% increase.

By allowing high occupancy vehicles (transit buses, or carpools/vanpools) carrying 2+ persons, and in some cases 3+ persons per vehicle to travel in the HOV lanes, the lanes increase the person carrying capacity and the Average Vehicle Occupancy (AVO) of a particular freeway. Furthermore, HOV lanes provide a travel-time incentive and increased trip reliability for buses, vanpools, and carpools, and also air quality benefits.

Funding: The preparation of this report was financed in part through grants from the United States Department of Transportation – Federal Highway Administration and the Federal Transit Administration – under provisions of the Transportation Equity Act for the 21st Century (TEA-21). Additional financial assistance was provided by the California State Department of Transportation.

Table 1

HOV SYSTEM MILEAGE (IN LANE MILES)			
	1990	2004*	% Increase
Southern California Region	54.9	664	1109%
United States	700	3000	329%

*Southern California region mileage is for year 2000

Sources: SCAG; HOV Facility Development: A Review of National Trends

Figure 2

Figure 3

The Southern California Association of Governments (SCAG) conducted this study for the purpose of analyzing the current performance of the HOV lane system in the region. The study area (see figure 1) consists of the counties of San Bernardino, Riverside, and Orange. Los Angeles County is not included in this study per se because the Los Angeles County Metropolitan Transportation Authority completed an *HOV Performance Program Evaluation Report* (The Parsons Brinckerhoff Study Team, November 2002) for Los Angeles County, which the SCAG study is designed to complement.

Key Findings

- Survey results show that the general public understands and strongly supports (76%) HOV lanes.
- Introduction of HOV lanes on freeways has been followed by a gradual growth of ridesharing and an increase in the life span of carpooling and vanpooling arrangements.
- Existing HOV lanes are well utilized, with most operating near full capacity during the peak periods.
- With the exception of a few instances where the HOV lanes themselves are congested, HOV lanes provide time savings ranging from one minute to fifteen minutes to rideshare vehicles per trip.
- There is no evidence that HOV Lanes are subject to a greater accident rate than other freeway lanes, per se. However, the installation of direct HOV-to-HOV connectors almost universally reduced accident rates in the vicinity of the affected intersections.

- Violation rates average 1.2% in the three study counties, well below the 10% level identified as a threshold for concern.
- Transit operations currently contribute relatively little to person movement on the HOV lanes in the study counties. However, increased transit service may offer significant opportunity to increase the person-carrying capacity of the existing HOV network.
- Modeling results indicate that regional VMT, VHT, and average speed are all optimized with a 2+ HOV lane system occupancy requirement. This is superior to a system with no occupancy restrictions, which in turn is superior to a 3+ occupancy restriction.

- Continued 24/7 operations of HOV lanes in the study counties is supported and warranted as congestion and peak spreading continue to grow.
- The public surveys express a preference for HOV lane separations from mixed flow lanes. Barrier or striped limited access HOV lanes encourages longer trips in the HOV Lane, and eases enforcement of violations.
- Current occupancy requirements are adequate at this time. Congestion on HOV facilities should be assessed on a case by case basis, and options for greater use of vanpools, transit, or restriping to add more HOV capacity, where feasible, should be considered, in addition to potential changes in occupancy requirements.
- Direct HOV-to-HOV connectors provide congestion relief for both carpoolers and solo drivers, reduce accident rates in the vicinity of congested interchanges, provide additional time savings for carpoolers,

and contribute to the continuity of the HOV network. As project costs increase, however, detailed analyses of accident reductions, congestion relief, and time savings are needed on a project-by-project basis to justify the investment of public funds.

Recommendations

- Continue all-day, all-week (24/7) HOV lane operations and limited access/egress locations.
- Address HOV lane congestion and bottlenecks individually.
- Continue to monitor HOV lane congestion and study strategies for converting HOV occupancy requirements on a case by case basis.
- Defer 3+ conversion strategies as long as possible. These should be one of the last strategies considered, not the first, and should be implemented only in conjunction with plans to fill excess capacity.

- Emphasize transit investments to increase vehicle occupancy.
- Complete the HOV lane system to capture all available system and traveler benefits.
- Support and maintain an ongoing program of HOV performance monitoring and reporting to support program evaluations
- Undertake future research regarding HOV lane design and implementation including validation of the PEMS data base and safety analysis.

REGIONAL HIGH-OCCUPANCY VEHICLE (HOV)LANE SYSTEM PERFORMANCE STUDY

SUMMARY REPORT

The Southern California Association of Governments (SCAG) conducted this study for the purpose of analyzing the current performance of the HOV lane system in the region. The study area (see Figure 1) consists of the counties of San Bernardino, Riverside, and Orange. Los Angeles County is not included in this study because the Los Angeles County Metropolitan Transportation Authority recently completed the *HOV Performance Program Evaluation Report* (The Parsons Brinckerhoff Study Team, November 2002) for Los Angeles County, which the SCAG study is designed to complement.

Key Findings: ***Existing HOV lanes are well utilized, with most operating near full capacity during the peak periods.***

Overview

Data Categories. The consultant team collected data in five broad categories: (1) Volumes and Occupancy; (2) Travel Times; (3) Air Quality; (4) Safety; and (5) Costs.

Data Gaps. In the eighties and nineties, when HOV lanes were first introduced in Southern California, each new lane was accompanied by an elaborate process of before and after data collection that documented not only the number of vehicles in the lane, but also time savings, violation rates, and accident impacts. Unfortunately, this extensive process of data collection did not survive into the late nineties and beyond. For example, vehicle occupancy counts were not regularly made in Orange, Riverside, and San Bernardino Counties between 1995 and 1999. Even when occupancy counts were made, moreover, travel times and time savings in the HOV lane were rarely documented.

Key Findings: *Introduction of HOV lanes on freeways has been followed by a gradual growth of ridesharing and an increase in the life span of carpooling and vanpooling arrangements.*

Volumes and Occupancy

Growth Over Time. Exhibit 1.1 plots Average Vehicle Occupancy (AVO) over time for two Orange County freeways, State Route 55 and I-5. The graph shows that AVO tended to increase following the introduction of HOV lanes on both freeways, indicating an increase in ridesharing. The construction of

freeway-to-freeway connectors on SR-55 and I-5 was also generally followed by an increase in AVO.

Over time, surveys (Billheimer and McNally, 2003) show that the HOV lanes tend to cause carpools to last longer, regardless of how they came to use the lanes.

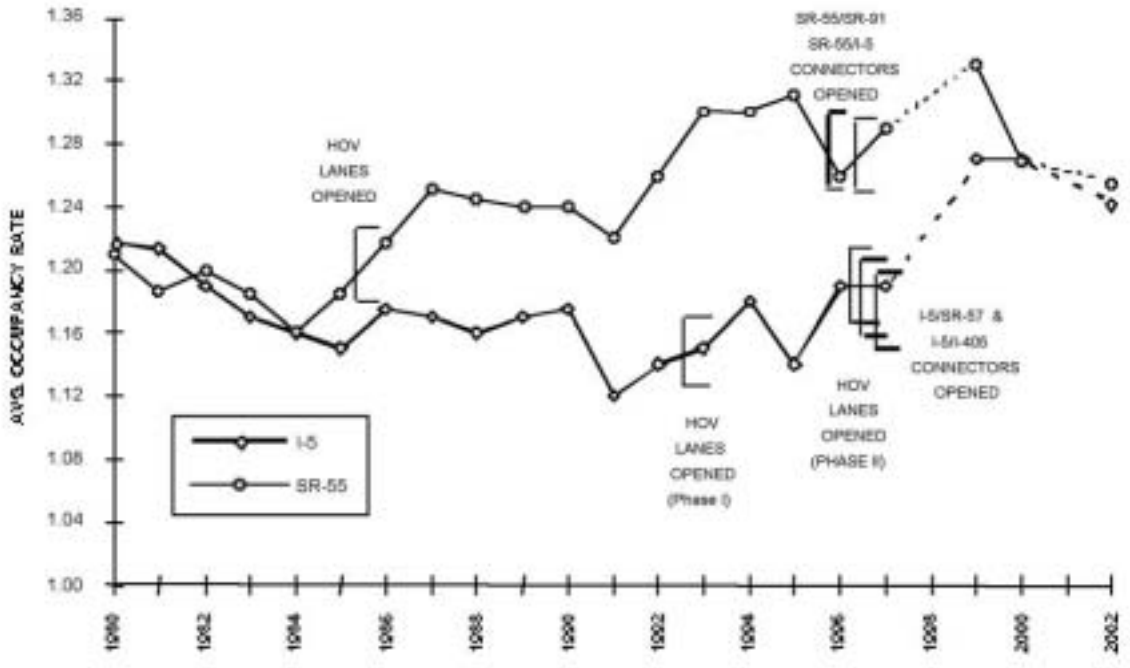
Current Vehicle Volumes. Recent vehicle volumes in the HOV lanes of the three study counties are graphed in Exhibit 1.2, which shows peak-hour and peak-period volumes in the peak direction of flow.

The horizontal lines of Exhibit 1.2 represent two generally recognized operating standards for HOV lanes: (1) The lower level of 800 vehicles per hour, which is generally recognized as the minimum operating standard for a mature HOV lane; and (2) The upper level of 1650 vehicles per hour, at which point free-flow operations can begin to deteriorate, although rates as high as 2100 vehicles per hour have been recorded on Southern California HOV lanes.

As indicated in Exhibit 1.2, with the single exception of State Route 71 in San Bernardino County, a new route which experiences little congestion on either HOV lanes or mixed-flow lanes, the HOV lanes in Orange, Riverside, and San Bernardino Counties are not in danger of falling victim

EXHIBIT 1.1

AVERAGE VEHICLE OCCUPANCY OVER TIME
SR-55 AND I-5, ORANGE COUNTY



Source: Klusza, 1987; Sullivan, 2000; CALTRANS District 12 HOV Reports (1999, 2000, 2002)

Key Findings: ***Existing HOV lanes are well utilized with most operating near full capacity during the peak periods.***

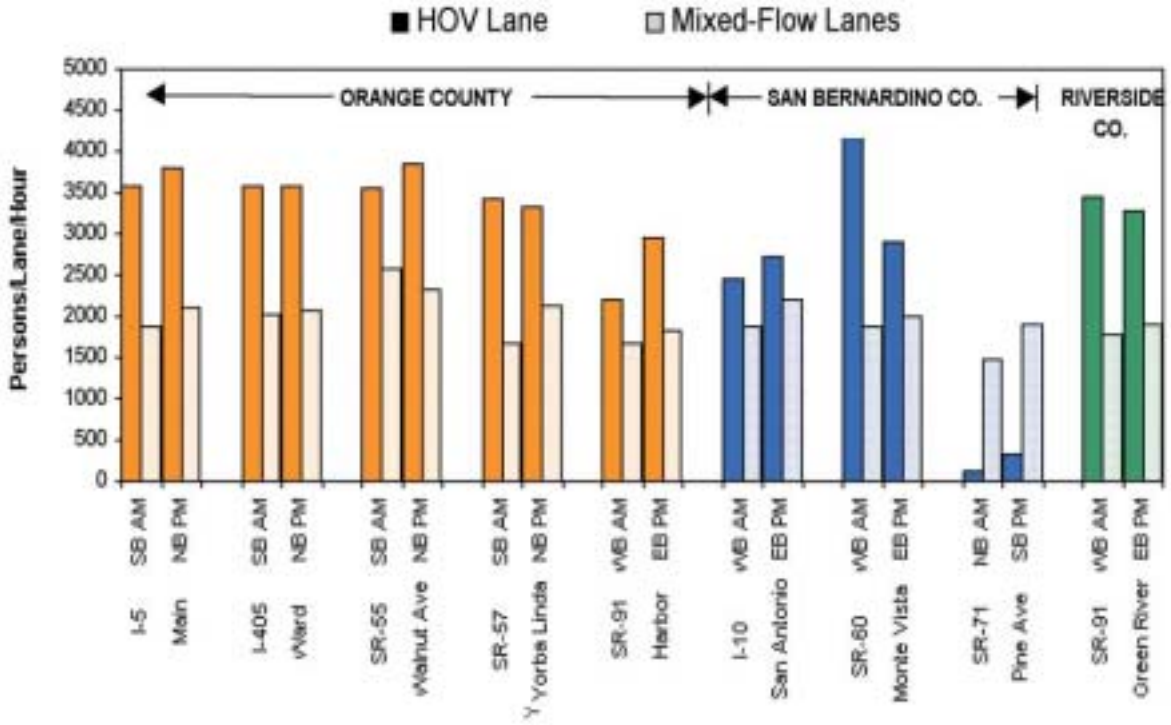
Key Findings: ***With the exception of a few instances where the HOV lanes themselves are congested, HOV lanes provide time savings ranging from one minute to fifteen minutes to rideshare vehicles per trip.***

to the "empty lane syndrome." Rather, most of these lanes are currently operating at or near the upper limits of their capacity, a fact which at times causes sufficient back-ups in certain locations to reduce or eliminate the time advantage offered to ridesharers.

Person Volumes. Exhibit 1.3 shows that, as would be expected, the person volumes carried by the HOV lanes are almost always significantly greater than the corresponding volumes in the mixed-flow lanes. HOV lanes in the study counties carry an average of 2,970 persons per hour during the peak hour, as compared with 1,962 persons per lane per hour in adjacent mixed flow lanes. The predominant person-carrying performance of the HOV lanes is achieved primarily through carpools, with relatively small contributions from buses.

EXHIBIT 1.2

PERSON VOLUMES FOR YEAR 2000
HOV LANES AND MIXED-FLOW LANES
ORANGE, SAN BERNARDINO, AND RIVERSIDE COUNTIES



Source: CALTRANS District 8 (2000) HOV Report; CALTRANS District 12 (2000) HOV Report

Speeds and Travel Times

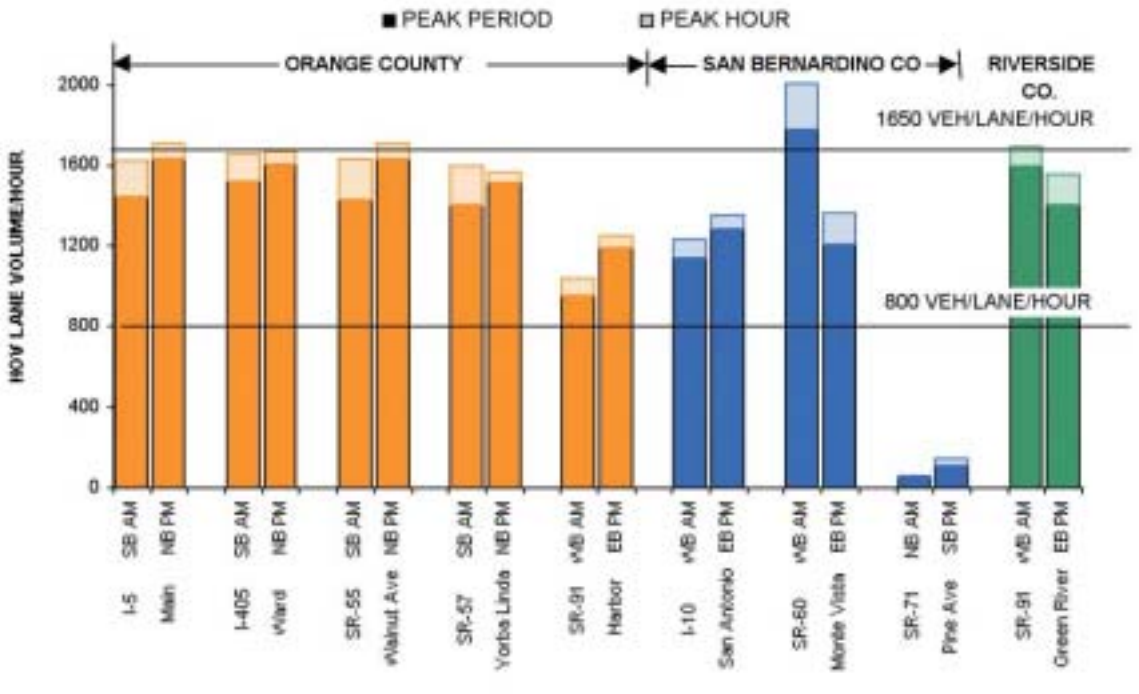
HOV Lane Time Savings. Exhibit 1.4 graphs the time savings available to vehicles traveling the full length of HOV freeway lanes in Orange and Riverside Counties (no data were available for San Bernardino County).

The data in the exhibit shows that mixed-flow lanes may actually be faster than the southbound I-5 HOV lanes during the morning peak period. This phenomenon reflects the impact of the "Orange Crush," where the two HOV lanes on I-5 and SR-57 feed and overload the single I-5 HOV lane south of the crush, causing a back-up which affords a time advantage for the mixed-flow lanes.

Key Findings: *There is no evidence that HOV Lanes are subject to a greater accident rate than other freeway lanes, per se. However, the installation of direct HOV-to-HOV connectors almost universally reduced accident rates in the vicinity of the affected intersections.*

EXHIBIT 1.3

HOV LANE VEHICLE VOLUMES FOR YEAR 2000
ORANGE, SAN BERNARDINO, AND RIVERSIDE COUNTIES

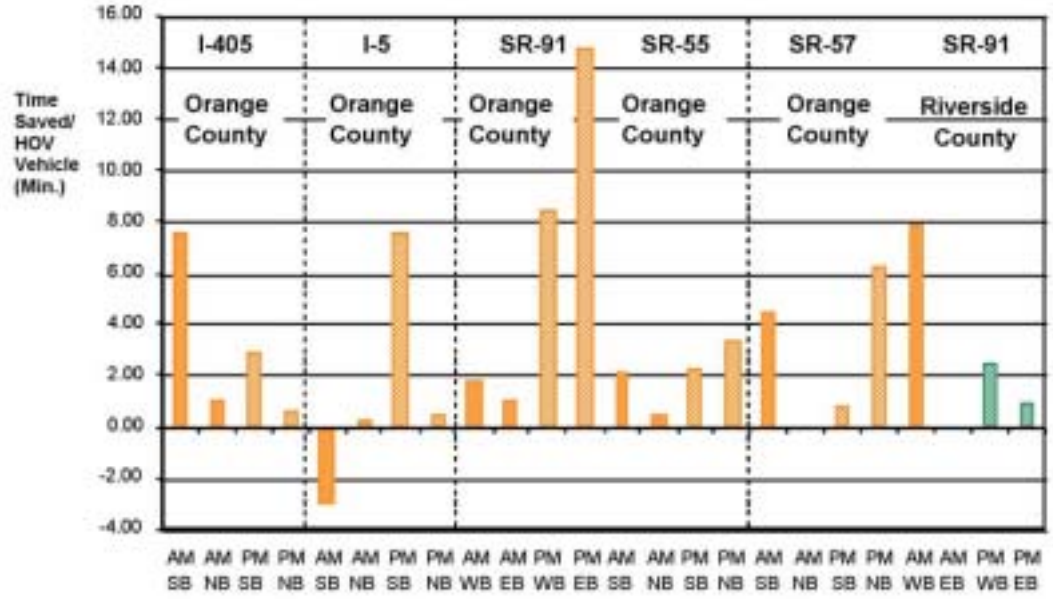


Source: CALTRANS District 8 (2000) HOV Report; CALTRANS District 12 (2000) HOV Report

Key Findings: Violation rates average 1.2% in the three study counties, well below the 10% level identified as a threshold for concern.

EXHIBIT 1.4

TIME SAVED IN ORANGE AND RIVERSIDE COUNTY HOV LANES (PER HOV VEHICLE)



Source: PeMS Data Base

Time Savings Per Mile. In Orange County, the time saved per mile of HOV freeway lane ranges from a loss of .08 minutes per mile on southbound I-5 in the morning to 1.11 minutes per mile on eastbound SR-91. Overall, the time saved per mile on all five of Orange County's HOV freeway lanes is 0.19 minutes per mile in the peak commute direction and 0.12 minutes per mile in the off-peak direction. The time saved on SR-91 in Riverside County amounts to 0.26 minutes per mile in the peak commute direction, and 0.07 minutes per mile in the off-peak direction.

Safety

HOV Freeway Lanes. In general, the installation of HOV lanes on freeways in Orange, San Bernardino, and Riverside Counties had no discernible impact on accident rates over the freeway segments involved.

In a few cases, such as State Route 10 in San Bernardino, the northernmost segment of I-5 in Orange County, and, SR-55 in Orange County, the installation of HOV lanes was accompanied by an increase in accident rates. The exact cause of these accidents is difficult to determine based

upon the available data. In the absence of definitive data, we are forced to conclude, along with the investigators at Cal Poly (Sullivan, et al., September 1992) and the LACMTA study (LACMTA, November 2002), that

"...no distinct trends or patterns were identified that can be attributed directly to facilities with carpool lanes versus facilities without carpool lanes."

HOV-to-HOV Connectors. The installation of HOV-to-HOV connectors linking Orange County HOV lanes have resulted in a decrease in accident rates in the vicinity of the freeway intersection. Imputed savings ranged from a reduction of 19 accidents per year in the vicinity of the SR-57/I-5 connector to 124 accidents per year for the SR-91/I-5 connector.

Enforcement and Violations

CHP enforcement activities have managed to keep violation rates on Southern California freeways well below the ten percent threshold identified as a benchmark for concern. Overall violation rates in Orange County averaged 0.4% in 2002, while the most recent data for San Bernardino and Riverside Counties show rates of 1.9% and 2.3%, respectively.

In June 2003, the SYSTAN team mailed surveys to 5,945 drivers observed using I-405, SR-55, and the SR-55/I-5 HOV-to-HOV connector. Surveys were sent to both carpoolers and solo drivers, and the mailing produced 764 completed surveys (12.9% of the total mailed). The surveys captured information on trip purpose, origins and destinations, travel times, ridesharing habits and propensities, demographic characteristics, and general attitudes toward Southern California's preferential lanes. Drivers responding to the survey were given the opportunity of volunteering for the three focus group discussions held at the office of the Orange County Transportation Authority.

Key Findings: ***Survey results show that the general public understands and strongly supports (76%) HOV lanes.***

Trip Characteristics

Purpose. The home-to-work commute was by far the most common trip purpose reported by respondents, accounting for 88.5% of all trips on the three routes.

Length. The average one-way trip length reported in all corridors was 20.7 miles. Ridesharers made longer trips than solo drivers, averaging 23.8 miles to 19.8 for non-ridesharers.

Ridesharing Characteristics

Incidence of Carpooling. Not all ridesharers use HOV lanes, and not all vehicles containing two or more occupants constitute regular carpools. Only 41% of the respondents characterizing themselves as

rideshares reported that they actually shared rides every working day of the month. On the other hand, respondents characterizing themselves as drive-alone commuters reported that they actually carpooled about one day every two months. Because solo drivers far outnumber ridesharers, this low incidence of occasional carpooling by solo drivers constitutes a significant portion of the carpools on the road. On I-405, for example, survey responses suggest that 24% of the total carpools observed on any given day are comprised of self-described "solo" drivers who just happen to be carrying a passenger.

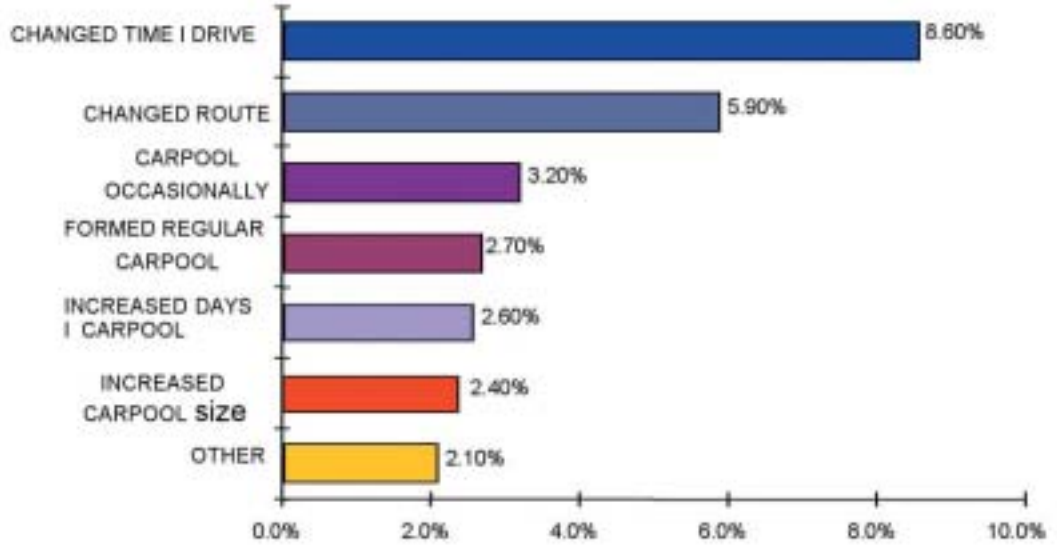
Key Findings: ***Transit operations currently contribute relatively little to person movement on the HOV lanes in the study counties. However, increased transit service may offer significant opportunity to increase the person-carrying capacity of the existing HOV network.***

Transit Use

Scheduled transit service comprises a very small portion of HOV lane usage in Orange, San Bernardino, and Riverside Counties. The most frequent bus-on-freeway service in the study counties is offered by the Orange County Transportation Authority's Route 205, which operates at fifteen minute headways during peak periods on Interstate 5. This service carries 3,658 passengers per day, far and away the largest use reported by any of the bus routes operating on freeways in the three study counties. By way of comparison, the El Monte Busway in Los Angeles County carries more than 24,500 passengers per day,

EXHIBIT 1.5

IMPACT OF HOV LANES ON DRIVING PATTERNS



Source: SCAG Mailback Survey (Billheimer and McNally, 2003)

suggesting that transit represents a largely untapped source of ridesharing on the HOV lanes of the study counties.

Carpool Formation. Fully 53.6% of the carpoolers responding to the survey had formed their carpool with other household members. Another 36% had gotten together with co-workers. Only 3.3% of all carpoolers surveyed said that company carpool programs had helped with the formation of their carpool, while only 2.2% cited ridematching services.

Carpool Duration. On the average, ridesharing respondents had been carpooling for 4.5 years. Drivers using I-405 and SR-55 HOV lanes reported identical carpool histories, averaging 4.3 years each. This is more than double the carpool longevity reported in 1989 by drivers on similar routes without bus carpool lanes. While the wording of the 1989 surveys did not correspond exactly to that used in the current survey, the sheer magnitude of the differences in longevity before and after the introduction of HOV lanes on the study routes suggests that bus/carpool lanes increase the length of time carpools remain in existence.

Carpool Lane Perceptions

Perceived and Actual Time Savings. Both carpoolers and solo drivers tended to overestimate the amount of time they could save by using the HOV lanes along their morning route. During the peak morning commute hour (8:00 to 8:59 a.m.), computer records showed a savings of 10.1 minutes for drivers traveling the length of the I-405 carpool lanes. Carpoolers using I-405 estimated their savings at 19.2 minutes, while solo drivers guessed 11.2 minutes. In the case of SR-55, computer data put the average peak hour savings at 5.7 minutes, as compared with carpooler estimates of 17.1 minutes and solo driver estimates of 12.3 minutes. Regarding trips through the I-5/SR-55 connector, speed runs showed peak hour savings of 5.0 minutes, well below average carpooler estimates of 13.8 minutes and solo driver estimates of 12.4 minutes.

Perceived Changes in Time Savings. Sixty-four percent of respondents felt that the time savings available in the HOV lanes had stayed about the same over the past year, while 23.3% thought the savings had decreased and 12.4% thought they had increased.

Reported Changes in Driving Patterns

In all, 10.1% of the solo drivers and 42.9% of the current carpoolers surveyed said that the HOV lanes had caused them to change their driving patterns in some way. "I changed the time I drive" was the predominant change noted by carpoolers and solo drivers alike reporting a change in response to the presence of HOV lanes. In all, 6.0% of the solo drivers surveyed and 16.0% of the carpoolers reported this change. Exhibit 1.5 breaks down the type of change reported by all responding drivers.

Carpool Lane Support

Drivers were asked to classify their support or opposition to having bus/carpool lanes on Southern California freeways. Answers showed strong support for HOV lanes, with 75.8% of all drivers expressing either support (32.7%) or strong support (43.1%) and only 11.7% expressing opposition. The remaining 12.6% of respondents were neutral.

TRAFFIC FORECASTS

Exhibit 1.6 displays the output of the regional transportation model of Orange, San Bernardino, and Riverside Counties to compare the daily performance of the transportation network under three different HOV occupancy scenarios.

1. A **Baseline** scenario for the year 2025 reflecting the committed projects on the draft SCAG 2004 Regional Transportation Plan;
2. A **3+ HOV System** in which the baseline HOV lane system is restricted to use by 3+ carpoolers and buses; and
3. An **Open-HOV System** in which all HOV lanes in the baseline network are opened to all vehicles with no restrictions.

Key Findings: ***Modeling results indicate that regional VMT, VHT, and average speed are all optimized with a 2+ HOV lane system occupancy requirement. This is superior to a system with no occupancy restrictions, which in turn is superior to a 3+ occupancy restriction.***

The direct comparison shows that the HOV system baseline alternative with 2+ occupancy requirement is the preferred alternative, supplying 19.7 million vehicles per day at an average speed of 23.9 miles per hour. Eliminating the HOV lane and opening the lanes to solo drivers increases the time spent in vehicles to 21.0 million hours and lowers

average speeds to 22.9 mph.[2] Implementing a 3+ occupancy requirement on all lanes gives the least attractive results of the three alternatives, raising the time spent traveling to 21.4 million vehicle hours and lowering speeds to 22.4 mph.

While the differences between alternatives may seem minimal, it should be pointed out that relaxing HOV lane restrictions entirely adds 1.3 million vehicle hours (an increase of 6.5%) to daily operations, which translates into an estimated $20 million per day in additional personnel costs. Tightening HOV restrictions by limiting occupancy to vehicles with three or more occupants, on the other hand, adds 1.7 million vehicle hours to the baseline total, an increase of 8.4%, or roughly $26 million per day in additional person time alone. Thus, the deterioration experienced under the 3+ restriction is even greater than that which results if the HOV lanes are opened to solo drivers with no entry restrictions. Modeling results support the continuation of the current HOV system 2+ occupancy option even under the highly congested conditions expected in 2025.

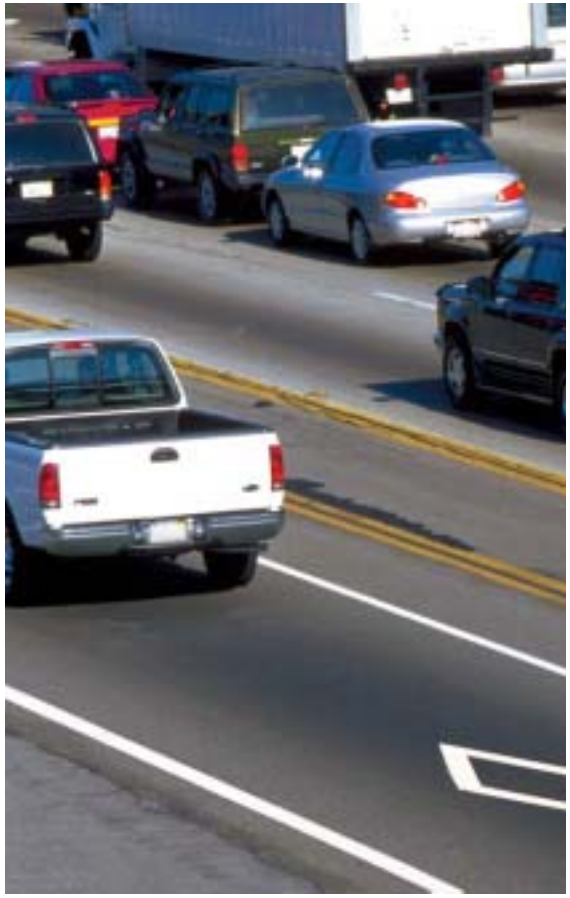
[2]This average speed reflects the average time spent traveling from origin to destination, and includes the time spent on arterial and off-freeway travel.

EXHIBIT 1.6

REGIONAL HOV PERFORMANCE STUDY
DAILY 2025 COMPARISON OF THREE OCCUPANCY SCENARIOS

OCCUPANCY SCENARIOS	DAILY PERSON TRIPS	VEHICLE-MILES TRAVELED	VEHICLE-HOURS TRAVELED	AVERAGE DOOR-TO-DOOR SPEED (MPH)
Baseline (HOV 2+)	57,444,240	471,445,919	19,709,318	23.9
HOV 3+ Scenario	57,410,097	479,317,162	21,367,732	22.4
Open HOV Scenario	57,477,372	481,202,976	20,989,874	22.9

Source: Meyer, Mohaddes Associates



Hours of Operation

Whereas HOV operating policies in Los Angeles, Orange, San Bernardino, and Riverside Counties operate for 24 hours, seven days per week, policies in Northern California tend to limit HOV restrictions to peak operating hours (i.e., 6 a.m. to 9 a.m. and 3 p.m. to 7 p.m.). These differences in policies can have an impact on operating speeds, congestion, delays, accidents, lane utilization, enforcement, and public acceptance.

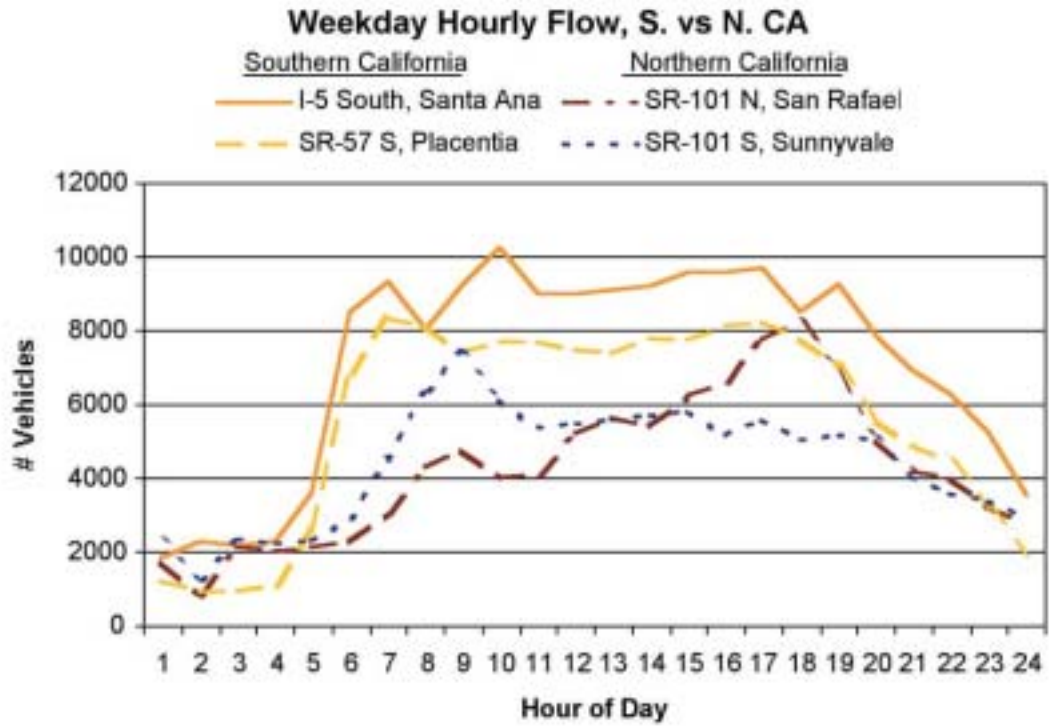
Key Findings: ***Continued 24/7 operations of HOV lanes in the study counties is supported and warranted as congestion and peak spreading continue to grow. Nearly every consideration, including spreading congestion patterns, heavy weekend travel, available time savings, low violation rates, regional consistency, the cost of changes, and public opinion.***

Congestion Patterns. A comparison of congestion patterns in the Southern California study counties with those in Northern California, where HOV lanes are restricted to peak weekday hours, shows that the peak operating hours in the Southern California counties typically last longer than the peaks on Northern California freeways. Exhibit 1.7 compares the peak flow patterns on four Northern and Southern California freeways with operating HOV lanes.

Whereas the two Northern California free-

EXHIBIT 1.7

TYPICAL HOUR-BY-HOUR VOLUMES ON FOUR CALIFORNIA FREEWAYS



Source: PeMS Data Base

ways, Marin Route 101 (in San Rafael) and Santa Clara Route 101 (in Sunnyvale) show pronounced peaks in the AM and PM, respectively, the two Southern California freeways, I-5 (in Santa Ana) and SR-57 in (Placentia) show equally heavy volumes during both morning and evening peaks, and no let-up during the middle of the day. In every case, the Southern California freeways peak earlier and the peaks last longer than those observed on Northern California freeways.

Discussions with CALTRANS officials in the three Southern California study counties suggest that the durations of both morning and evening periods are spreading as traffic congestion increases. In Orange County, moreover, the popularity of such recreational destinations as Disneyland, Knotts Berry Farm, and Anaheim's Edison International Field keeps the freeways congested on the weekends as well.

Key Findings: *The public surveys express a preference for HOV lane separations from mixed flow lanes. Barrier or striped, limited access HOV lanes encourages longer trips in the HOV Lane, and eases enforcement of violations.*

Enforcement Impacts. Hourly restrictions on HOV lane usage have a clear impact on violation rates. The most prominent of these impacts are fringe effects. When HOV restrictions apply only to peak periods, the preponderance of violations occur at the fringes of the operating hours, just after restrictions come into play and just before they are removed. Presumably, motorists on the road at the legal changeover times are either unaware of the time, lazy about obeying the law so close to the time at which they could use the lane legally, or assume that an unwritten "grace period" exists. This is one of the reasons why violation rates in Northern California, which average 6.6%, are considerably higher than those in the three study counties, where the overall average is 1.2%.

Access/Egress Restrictions

All HOV lanes in Orange, San Bernardino, Riverside, and adjoining Los Angeles County have a buffer separating general traffic from HOV traffic and limiting access and egress to and from the HOV lanes to selected stretches of freeway. For the most part, the buffer zone is no more than freeway striping, although the width and striping of the buffer varies between facilities, and in certain spots, an actual physical barrier separates HOV and general purpose lanes. By way of contrast, HOV lanes in Northern California are contiguous with general purpose lanes, so that drivers may enter or exit the HOV lanes at any point along their length.

Control of HOV Lane Demand. An investigation of the relative number of carpools inside and outside of HOV lanes in Northern and Southern California can provide some insight into the influence of limited access on HOV lane use. HOV lane observations by CALTRANS District 12 showed that, on the average, 36.0% of Orange County carpoolers were traveling outside of HOV lanes when observed. Similar observations by CALTRANS District 8 found that 33.9% of the carpoolers in San Bernardino and Riverside Counties were not using the adjacent HOV lanes when counted. These percentages are relatively high compared to the corresponding percentages on the continuous-access HOV lanes in the San Francisco Bay Area, where the percentage of carpoolers observed outside carpool lanes during the peak period was 20.2%.

The significant difference between the 36.0% of Orange County carpoolers and the 33.9% of San Bernardino and Riverside County Carpoolers who choose not to use Southern California's limited-access HOV lanes and the 20.0% who choose not to use the unlimited-access lanes in the Bay Area may not be attributed entirely to the difference in access design. As the speed data show, there are a few spots in Southern California where the mixed-flow lanes actually provide faster travel times than the adjacent HOV lanes. At these locations, it is only natural that carpoolers would avoid using the HOV lanes

The relatively large percentage of carpoolers outside of Southern California's HOV lanes highlight the relative flexibility of both the 2+ occupancy requirements and controlled lane access. While carpoolers may not wish (or need) to take advantage of carpool lanes during their morning commute on a particular day, the lanes may provide an advantage during the evening commute, or during the morning commute on another day. This flexibility is not available with a 3+ definition, where the HOV lanes are kept free-flowing at the expense of added congestion in the mixed-flow lanes. In this context, the limited access design of Southern California's HOV lanes exerts a positive influence on lane operations by discouraging short trips and keeping the HOV lanes from overcrowding.

Key Findings: ***Current occupancy requirements are adequate at this time. Congestion on HOV facilities should be assessed on a case by case basis, and options for greater use of vanpools, transit, or restriping to add more HOV capacity, where feasible, should be considered, in addition to potential changes in occupancy requirements.***

Impact on General Purpose Traffic. The potential impacts of access/egress separation on general traffic can be quite complex and there are no studies to suggest that buffer separations have a systematic positive or negative effect on general traffic.

The recent and planned investments in direct access ramps and HOV-to-HOV connectors serve to reduce the impact of HOV traffic on adjacent mixed flow traffic by isolating the HOV stream and eliminating the need for "white knuckle merges" as HOV drivers weave across congested mixed-flow traffic to reach designated entry and exit points.

Enforcement. The buffers limiting HOV lane access and egress introduces an additional opportunity for a traffic violation and, consequently, additional enforcement responsibilities. As a practical matter, this opportunity evidently makes only marginal increases on the burden shouldered by enforcement officers, since a past study of HOV lane violations (Billheimer, January 1990) found that buffer violations accounted for only 16% of the citations issued by officers assigned to special HOV enforcement in areas having access/egress restrictions.

Occupancy Requirements

All HOV lanes in Orange, San Bernardino, and Riverside Counties are currently reserved for carpools with two or more occupants. This occupancy restriction is currently in place in almost all of Southern California's HOV lanes. The only exception is the El Monte Busway (I-10), which operates with a 3+ requirement during the peak period and allows 2+ operations during non-peak periods.

HOV Lane Utilization. Exhibit 1.8 plots the peak hour volume experienced by the HOV lanes of Orange County and the Inland Empire if occupancy requirements are raised to a minimum of three persons and existing three-person carpools are joined by ten percent of existing two-person carpools (an increase of 98%). In no case does the peak-hour volume in any of the lanes exceed the minimum level of 800 vehicles per hour cited by HOV guidelines as the minimum threshold for avoiding the "empty lane syndrome."

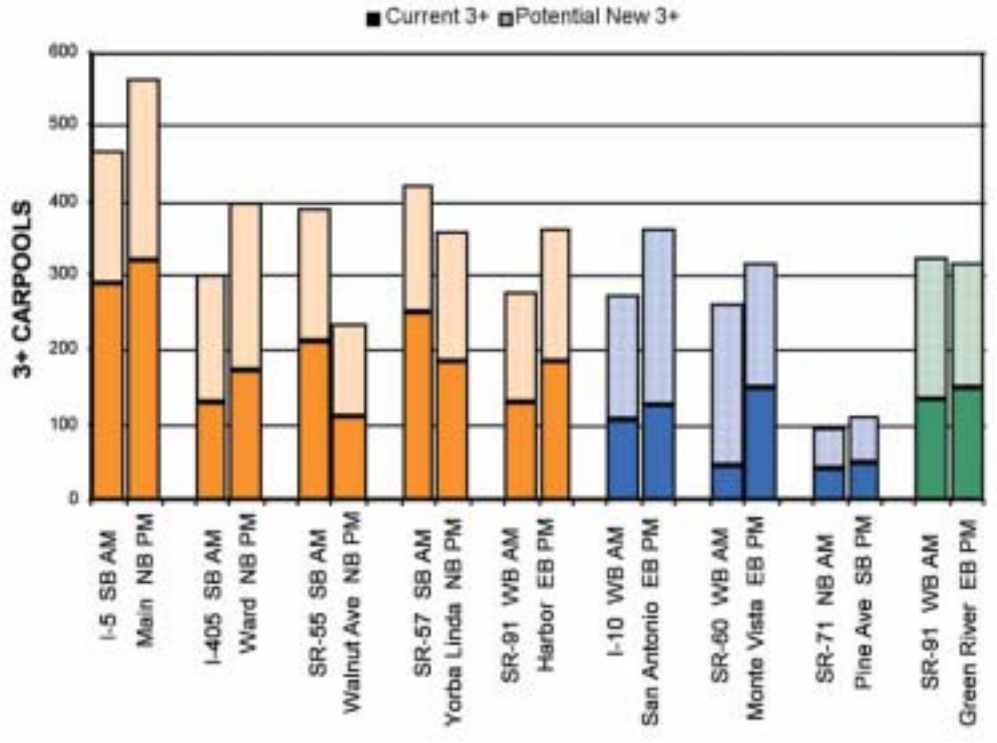
Impact on Mixed Flow Traffic. Conversion of HOV lanes from a 2+ to 3+ occupancy requirement may result in significant diversion of existing 2+ users back into the mixed flow lanes. On the average, conversion today of existing 2+ lanes to a 3+ requirement would deliver over 1,000 additional vehicles during the peak hour to the mixed flow lanes. Given the additional load, which greatly exceeds the number of vehicles and persons remaining in the HOV lanes, severe congestion would likely result in the mixed-flow lanes.

Enforcement. The HOV Lane Design Notes included in SYSTAN's HOV Lane Violation Study (Billheimer, January 1990) observe that the difference between a 3+ carpool requirement and a 2+ carpool requirement has a minimal impact on enforcement requirements. "Violators are somewhat easier to recognize when the definition is 3+, but a 2+ requirement will lower the total number of violators slightly (while lowering the violation rate significantly, since there will be more legitimate carpoolers in the lane)."

Safety. Safety, which is so dependent on design features and congestion patterns, remains the key unknown in HOV lane operations and is largely site specific. In theory, there need be no safety differences between operating a 2+ HOV lane and operating a 3+ HOV lane. If the 3+ HOV lane is created overnight by changing the minimum occupancy of a congested HOV lane from 2+ to 3+, however, the ensuing shifts to the adjacent mixed-flow lanes could lead to increased accidents. Freeway accidents shot up roughly 150% over the life of the Santa Monica Freeway Diamond Lane Project, as non-HOV traffic forced out of the preferential lane contributed to congestion in the main line lanes.

EXHIBIT 1.8

TOTAL 3+ CARPOOLS IN ORANGE, SAN BERNARDINO AND RIVERSIDE COUNTIES



Source: SYSTAN; CALTRANS District 8 HOV Report (2000); CALTRANS District 12 HOV Report (2000)

Public Perceptions. Orange County focus group participants considering the prospect of a switch from 2+ to 3+ occupancy requirements registered near-universal disapproval for the idea (Billheimer and McNally, 2003). Public support for HOV lanes in Southern California is very high at the present. Over three quarters of the respondents to the mail-back survey expressed either support or strong support for bus/carpool lanes.

HOV-to-HOV Connectors

Overview. Direct HOV-to-HOV connectors are a relatively new element of the regional HOV system. In the five years between 1996 and 2001, six new connectors were

constructed in Orange County to permit direct transfer from one HOV lane to another, thereby minimizing weaving conflicts and enabling ridesharing vehicles to maintain their speed advantage through the interchanges. Another connector linking I-405 and SR-55 was under construction during the current study, and six more have been included in the 2004 Regional Transportation Plan (two each in Orange, Riverside, and San Bernardino counties).

Connector Benefits. HOV-to-HOV connectors afford a number of benefits to drivers using the freeway networks. Since the connectors are installed at "chokepoints" where congestion tends to increase as cars maneuver to make the transition from one freeway to another, the connectors immediately provide congestion relief for HOV drivers and solo drivers alike. This congestion relief is reflected both in time savings and reduced accident rates. Connectors also contribute to the continuity of the HOV network, making it possible for carpoolers using more than one freeway to travel from the on-ramp of their initial freeway to their final freeway off-ramp without leaving the HOV lane to change freeways. Where congestion still exists for solo drivers following the implementation of HOV-to-HOV connectors, the connectors offer an incentive to carpool in the form of peak period time savings.

Because no before/after records were kept documenting the time savings realized by carpoolers and non-carpoolers when Orange County's HOV-to-HOV connectors were completed in the late 1990's, it is difficult to asses the magnitude of the savings realized initially by removing merging carpoolers from the stream of traffic using the mixed-flow connectors, It is possible, however, to document changes in accident rates in the vicinity of interchanges improved by direct connectors and to estimate the time-savings currently available to carpoolers using the HOV-to-HOV connectors in today's traffic patterns. Accident reductions in the vicinity of direct Orange County connectors ranged from 19 accidents per year to 124 accidents per year, and the time savings afforded to carpoolers using these connectors ranged from zero in off-peak directions to a high of 4 minutes during the morning peak on the connector linking I-5 and SR-55.

Benefit/Cost Analysis. Procedures were developed for a benefit/cost analysis consolidating the disparate elements of project cost, time savings, congestion relief, and accident reduction into a consistent format

Key Findings: ***Direct HOV-to-HOV connectors provide congestion relief for both carpoolers and solo drivers, reduce accident rates in the vicinity of congested interchanges, provide additional time savings for carpoolers, and contribute to the continuity of the HOV network. As project costs increase, however, detailed analyses of accident reductions, congestion relief, and time savings are needed on a project-by-project basis to justify the investment of public funds.***

for prioritizing the construction of proposed HOV-to-HOV connectors. Because the time savings available for future connectors were difficult to estimate, the analysis produced a "break-even" time savings that reflected the savings which carpoolers would have to realize to justify the cost of the connectors over a fifty-year time horizon. While the findings were heavily site dependent, the following general guidance resulted from an application of this technique to planned future projects:

- Project costs under $50 million could generally be justified solely on the strength of anticipated accident reductions and immediate congestion relief for mixed-flow traffic.
- Project costs between $50 and $150 million could generally be offset by accident savings, congestion relief, and a minimal time savings ranging between 2 and 4 minutes per carpool vehicle.
- Project costs over $150 million required detailed analysis of accidents, congestion, and connector flows to justify the investment of public funds.

The findings of the HOV lane system performance study support the following recommendations for future actions. They are not presented in any order of priority.

Continue Policies of 24/7 Operations and Limited Access/Egress Locations

The operation of HOV lanes on a 24/7 basis is overwhelmingly supported by the public, and increasing congestion patterns through the midday period and on weekends argue strongly for a continuation of the current 24/7 operating policy. The public also understands and supports the practice of using striped buffers to restrict access and egress to the HOV lane and prevent traffic from weaving in and out of the lanes. The fact that limited access helps to discourage short trippers from using the already crowded HOV lanes offers another strong argument for controlling HOV lane access and egress.

Address Carpool Lane Congestion and Bottlenecks Individually

Locations where HOV lanes are experiencing growing congestion should be dealt with on a case by case basis. HOV lane backups and bottlenecks vary, but a significant number are the result of excessive demand relative to HOV lane capacity. An example is the "Orange Crush" where I-5 and SR-57 HOV lanes feed into a single southbound HOV lane on I-5. CALTRANS has proposed eliminating this backup by adding a second HOV lane south of the HOV-to-HOV connector to accommodate the additional carpool volumes. This proposed addition should be accorded high priority and similar fixes should be explored at other system bottlenecks and lane drops. It should not be assumed that the solution to HOV lane

congestion is to raise HOV occupancy requirements. This could be counter-productive to the overall operation of the freeway.

Continue to Monitor HOV Lane Congestion and Study Strategies for Converting HOV Occupancy Requirements on a Case by Case Basis. Defer 3+ Conversion Strategies as Long as Possible. These should be One of the Last Strategies Considered, Not the First, and should be Implemented only in Conjunction with Plans to Fill Excess Capacity.

Converting existing 2+ carpool lanes to 3+ lanes could potentially alleviate the growing congestion within the HOV lanes. However, diversion of existing 2+ carpools out of the existing HOV lane and back into adjacent mixed-flow lanes will cause significant additional congestion on those lanes. The loss of time from this shift is likely to offset or exceed the savings to HOV 3+ users, especially if conversion rates from 2+ to 3+ carpools remain as low as past experience suggests. Converting congested 2+ lanes to 3+ lanes, without adding more capacity, would resemble a take-a-lane strategy that is likely to result in significantly increased mixed-flow congestion. Further study should be done on the possibility of extending capacity through additional transit service, increased marketing of van pools, and, where feasible, introducing additional 2+ lanes to expand HOV capacity.

Emphasize Transit Investments to Increase Vehicle Occupancy on the HOV Lane System.

Transit operations currently contribute relatively little to person movement on the carpool lanes in the study counties. However, increased transit service may offer significant opportunity to increase the person-carrying capacity of the existing HOV network. SCAG's Transit Advisory Committee should work with transit operators to assess opportunities for expanded service in HOV corridors, using the success of the El Monte Busway as a model.

Complete the Carpool Lane System to Capture All Available System and Traveler Benefits.

Complete the planned HOV lane system for Orange, San Bernardino and Riverside Counties. Fill critical HOV system gaps and, where cost effective and operationally sound, complete planned HOV-to-HOV connectors. Where system gaps exist, friction from additional HOV lane merging contributes to spot congestion and delays for all traffic. Surveys show that carpoolers and non-carpoolers alike overwhelmingly support HOV lane expansion and connector construction.

Support and Maintain An Ongoing Program of HOV Performance Monitoring and Reporting to Support Program Evaluations.

Southern California maintained an aggressive data collection program to monitor HOV lane use during the eighties and early nineties. This program of HOV data collection needs to be supported and maintained on a ongoing basis to provide improved data for operations and planning. Key information on HOV lane vehicle volumes, occupancy, violation rates, and speeds relative to adjacent mixed-flow lanes should be monitored on an ongoing basis to provide support for updating the Regional Transportation Plan and periodic reviews of HOV lane operations and policies. Before-and-after studies of performance on specific HOV lane corridors and proposed HOV-to-HOV connectors should also be encouraged to allow for a better tracking and estimation of project benefits.

Future Research Should Be Undertaken Regarding HOV Lane Design and Implementation. Key Research Topics Would Include:

Validation of the PeMS Data Base. The Freeway Performance Measurement System currently under development by CALTRANS and the University of California at Berkeley holds the promise of providing invaluable ongoing information on vehicle volumes, travel times, and delays on mixed-flow lanes and adjacent HOV lanes. Every attempt should be made to validate the use of the loop detector information in this database and compare it with traffic in the adjacent mixed-flow lanes so that system reports can be used to monitor HOV lane performance.

Accident Analysis. Research is needed to document the impact of specific HOV projects on accident rates and identify those configurations and/or operating policies which either increase or decrease accident rates.

REGIONAL HIGH-OCCUPANCY VEHICLE (HOV)LANE SYSTEM PERFORMANCE STUDY

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